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What Effect Does Vegetarianism Have on the Mineral Density of Bones?

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Abstract: Background: Low calcium intake in vegetarians can negatively impact bone health, with factors like oxalate, phytate, and fiber reducing calcium bioavailability. However, long-term effects on calcium retention and density are not proven. Calcium intake is crucial for bone health and preventing osteoporosis. **Aims:** This research aims to investigate the impact of a vegetarian diet pattern on our studied Jordanian BMD while taking the impactful effects of calcium supplementation. **Methods:** A study examining 328 patients with suspected osteoporosis, osteopenia, or osteoporotic fractures at Prince Rashid bin Al-Hussein Military Hospital between August and October 2023, used data from the hospital's medical record system and dual energy X-ray absorptiometry database. The study categorized the vegetarian diet pattern into four groups based on frequency of adherence and the number of calcium supplements taken per week. The analysis of covariance (ANCOVA) was conducted to determine the means, standard errors, and confidence intervals for patients' bone mineral density (BMD) in each category of the investigated vegetarian diet patterns. A chi-square was conducted to abstract distribution rates and their level of significance. The study was approved by the Jordanian Royal Medical Services' Institutional Review Board (IRB) committee on July 11, 2024. **Results:** This study analyzed 328 patients, with 93 following an infrequent vegetarian diet pattern, 82 following an intermittent vegetarian diet pattern, 84 following a frequent vegetarian diet pattern, and 69 following an always vegetarian diet pattern. The age groups were divided into four categories: under 50, 50-59, 60-69, and 70 or older. The gender distribution was statistically significant, with 82.6% of patients being females and 17.4% males. Obesity statuses were classified based on body mass indexes, and the distribution of calcium supplementation patterns varied among the four groups. Functionality was also significantly distributed across the groups, while physical activity levels were insignificant. The femoral hip and lumbar bone mineral densities were statistically distributed across the four groups. The ANCOVA analysis revealed that patients' BMD had Means±SDs of 0.9174±0.16351 g/cm², 0.9039±0.17476 g/cm², 0.9098±0.13927 g/cm², and 0.8791±0.13657 g/cm² for the four vegetarian diet patterns. **Conclusion:** The study found that a vegetarian diet significantly impacts bone mineral density in Jordanian patients, potentially increasing their risk of osteoporotic fractures. This effect was more pronounced when the diet shifted to a vegan one, even after accounting for supplemental calcium. The study suggests conservative strategies when transitioning to a vegetarian diet, rather than relying solely on supplements.

Keywords: Vegetarianism; Bone mineral density; Calcium absorption; Dietary vegetables content; Risk of osteoporotic fracture

INTRODUCTION

Osteoporosis is considered a "silent" disease, as it is asymptomatic until a fracture actually occurs. As a result, the general assumption has been that only the occurrence of fractures can be considered a relevant outcome of the process of osteoporosis. The morbidity and mortality associated with fractures are typically high, with the residual loss in function after a hip fracture in the elderly being particularly severe. 1-4

The importance of bone mineral density loss and osteoporosis is significant for the elderly, as the prevention of fractures and possible permanent loss in function is of particular high significance. A recent study on US adults estimated that increased life expectancy after the age of 50 has resulted in compression of morbidity among most age groups and sexes, meaning a decreased number of years with poor health. The prevention of fractures by whatever means is now more important than ever before. Indeed, a cross-sectional study of 3279 individuals in Europe, the United States, and Australia indicated that the health-related quality of life measured by the "health utilities index" in postmenopausal women with radiographically documented vertebral fracture was significantly impaired, having a direct negative relationship with the number of fractures. The first leakage into the vertebral integrity resulting from bone mineral density loss can have long-term effects on the quality of life, which is important as the use of vertebral x-rays and other medical examinations to diagnose osteoporosis is not rare. 5-8

With 10% of the population being vegetarians, understanding the implications of a vegetarian diet on bone health is crucial for healthcare professionals. Vegetarians are individuals who avoid consumption of animal flesh and related products, leading to the belief that they are healthier than non-vegetarians. Vegetarianism varies in its extremity, with the most extreme being vegans who do not consume any animal products or by-products such as eggs, dairy products, honey, wool, or leather. 9-12

A study in China found that elderly Buddhist nuns who are vegetarians due to their religion had significantly lower radial bone mineral density (BMD) compared with their omnivorous counterparts. This is due to the belief that vegetarians have a more alkaline diet due to their high fruit and vegetable intakes, which are believed to neutralize dietary acid loads and prevent the effects of low protein and calcium intakes on BMD. However, increased fruit and vegetable intakes have been shown to not affect calcium excretion and there are no studies that have looked at the relationship between dietary acid loads and BMD in vegetarians. Generally, those who have had a positive calcium balance throughout their lives, such as in rapid growth periods of childhood, adolescence, or pregnancy, will greatly reduce the loss of bone mass during menopause and the elderly years, delaying or possibly preventing osteoporosis. 13-17

Vegetarian diets and calcium intake are significant factors in bone health, with many studies revealing that vegetarians and vegans tend to consume lower amounts of calcium compared to non-vegetarians. In conclusion, understanding the impact of a vegetarian diet on BMD and osteoporosis is essential for healthcare professionals and the general public. By focusing on the effects of a vegetarian diet, individuals can better manage their bone health and reduce the risk of osteoporosis. 18-22

Many studies have shown that vegetarians have lower protein quality, calcium, and vitamin D intakes, which are essential for attaining optimal peak bone mass and preserving bone mass in the elderly. 23-25 It is therefore pertinent to study BMD in vegetarians who have low intakes of these nutrients. This research aims to investigate the impact of a vegetarian diet pattern on our studied Jordanian BMD while taking the impactful effects of calcium supplementation.

METHODS

This retrospective study aims to analyze the entire group of patients who attended the rehabilitation and rheumatology clinic at Prince Rashid bin Al-Hussein Military Hospital between August and October 2023. This study encompasses 328 clients who are suspected to have osteoporosis,

osteopenia, or are at risk for osteoporotic fracture. These clients had accessible data from our institutional medical record system (Hakeem) and from the recordable data on the dual energy X-ray absorptiometry database. Any patient who has missing retrievable data exceeding the upper limit of 20% or has an unknown diagnosed cause of secondary osteoporosis were excluded from this study. This study had been approved by Jordanian Royal Medical Services' Institutional Review Board (IRB) committee at 11 July 2024 under the registration number of 18_7/2024. Owing to its retrospective design, patients' informed consent forms were waived in this study.

In this study, the vegetarian diet pattern was categorised into four ordinal categorical groups. These groups were based on the frequency of adherence to the diet, ranging from infrequent (not more than 2 days per week), intermittent (3-4 days per week), frequent (5 days per week), and always (6-7 days per week). Similarly, the calcium supplement pattern was also classified into different categories based on the number of tablets taken per week (ranging from 0 to 14 tablets per week). The standard dosage for calcium supplement is one tablet taken twice daily. The categories are as follows: infrequent (0-4 tablets per week), intermittent (5-8 tablets per week), frequent (9-11 tablets per week), and always (12-14 tablets per week).

Table 1: Pairwise Comparisons

Dependent Variable: HBMD						
(I) VeganPattern_Cat14	(J) VeganPattern_Cat14	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
Infrequent 0-2 per week	Intermittent 3-4 per week	.334*	.001	.000	.332	.335
	Frequent 5 per week	.667*	.001	.000	.665	.669
	Always 6-7 per week	1.000*	.001	.000	.997	1.003
Intermittent 3-4 per week	Infrequent 0-2 per week	-.334*	.001	.000	-.335	-.332
	Frequent 5 per week	.334*	.001	.000	.332	.335
	Always 6-7 per week	.666*	.001	.000	.664	.669
Frequent 5 per week	Infrequent 0-2 per week	-.667*	.001	.000	-.669	-.665
	Intermittent 3-4 per week	-.334*	.001	.000	-.335	-.332
	Always 6-7 per week	.333*	.001	.000	.331	.334
Always 6-7 per week	Infrequent 0-2 per week	-1.000*	.001	.000	-1.003	-.997
	Intermittent 3-4 per week	-.666*	.001	.000	-.669	-.664
	Frequent 5 per week	-.333*	.001	.000	-.334	-.331
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

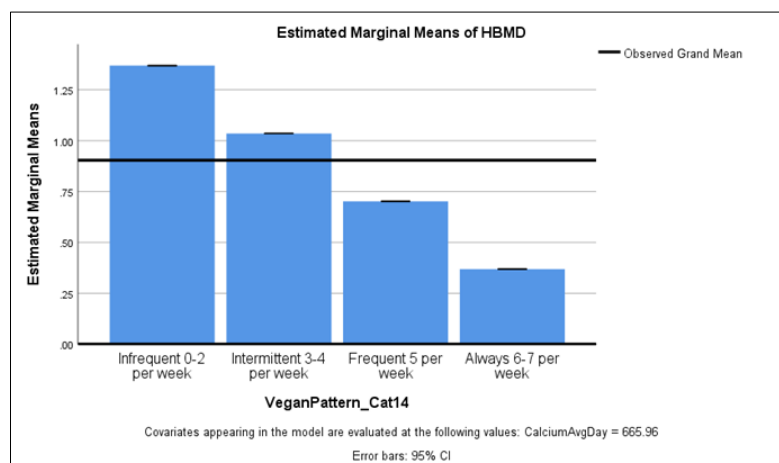


Figure 1: Estimated Marginal Means of HBMD

This study was initially investigated conducted the analysis of covariance (ANCOVA) statistically test by adopting the four vegetarian diet patter as an independent variable and the test attended patients' BMD as the primary dependent variable while the average daily calcium administration in mg as the affected covariance taking into consideration that each calcium carbonate (CaCO₃) tab contains 500 mg elemental of calcium. In the conducted ANCOVA analysis we determined the means±standard errors and confidence intervals for the patients BMD in each category of the investigated vegetarian

diet pattern's categories. A pairwise comparisons and F-test were also revealed, and the marginal means of dependent the patients' BMD were illustrated.

Considering the patients' vegetarian diet four patterns as a reference comparison for the several investigated categorical variables, a chi square was conducted to abstract the distribution rates across these comparative groups with their level of significance (p-value). Microsoft Office LTSC Professional Plus 2021 Excel Will be utilised to collect and organise patients' data. IBM SPSS Statistics version 25 will be used for statistical analysis and summarising the results of the study. This study will opt a significance level of 0.05.

RESULTS

The total number of patients tested in this study was 328. Among them, 93 followed an infrequent vegetarian diet pattern (Group I), 82 followed an intermittent vegetarian diet pattern (Group II), 84 followed a frequent vegetarian diet pattern (Group III), and 69 followed an always vegetarian diet pattern (Group IV). The age groups in this study were classified into four consecutive categories, beginning with the category of individuals under 50 years old, followed by the 50-59 age category, the 60-69 age category, and finally the category of individuals aged 70 or older.

The number of patients in each age category was as follows: 42 (12.8%), 86 (26.2%), 105 (32%), and 95 (29%). The gender distribution rates across Group I-IV were statistically significant, with approximately 82.6% (271 females) and 17.4% (57 males) in total. The obesity statuses in this study were categorised in a sequential manner according to the body mass indexes of the tested patients, ranging from underweight to normal weight, overweight, obese class I, and obese class II.

These obesity statuses were significantly distributed among the four compared vegetarian diet patterns. In the case of the tested patients, the pattern of calcium supplementation was classified, as previously mentioned in the method section, into four categories: infrequent, intermittent, frequent, and always.

The distribution of calcium supplementation patterns was significantly varied among Group I-IV. The patients' functionality, graded from maximal functionality (Grade I) to the worst functionality (Grade IV), also exhibited statistically significant distribution rates across Group I-IV. On the other hand, the physical activity levels of the tested patients, classified as low, moderate, and high in this study, showed statistically insignificant distribution rates. The femoral hip and lumbar bone mineral densities of the patients were statistically distributed across the four groups being compared.

When we conducted the ANCOVA analysis, we revealed that the patients' BMD had Means \pm SDs of 0.9174 \pm 0.16351 g/cm², 0.9039 \pm 0.17476 g/cm², 0.9098 \pm 0.13927 g/cm², and 0.8791 \pm 0.13657 g/cm² for patients' vegetarian diet pattern Groups I, Group II, Group III, Group IV, respectively. And Group I-IV average of 0.9040 \pm 0.15517 g/cm².

DISCUSSION

Preventing osteoporosis in vegetarians is crucial due to their diet containing low protein and calcium. Vegetarians have a 30% lower mean protein intake compared to meat eaters, which is beneficial for bone health. Protein is an important but often overlooked factor in maintaining bone health. A balanced diet with plenty of fruit and vegetables is beneficial for bone health. Alkali found in fruit and vegetables buffers acid caused by protein and increases calcium retention. Although an alkali-rich diet is bad for calcium stone formation, it is good for bone health. Low calcium stone formers actually have higher bone mineral density due to the calcium salts from the bone, which buffer the acid that causes stone formation. Vitamin K is also an important factor, and low intake is associated with increased hip fractures. Nutritional strategies for maintaining bone health in vegetarians include improving their knowledge of all aspects of healthy eating to gain nutrients and minerals necessary for maintaining bone health. Vegetarians should not consume vast amounts of milk, cheese, or full-fat dairy foods to meet calcium requirements. There are various foods and nutritional strategies that can be used to maintain a healthy bone status. The impact of vegetarianism on bone mineral density is also significant. Cross-cultural studies suggest that the usual low calcium intake of many vegetarians is a risk factor for detrimental bone health. 23-25

Factors that can reduce the bioavailability of calcium in vegetarian diets include oxalate, phytate, and fiber, which are found in spinach and some other leafy greens, whole grains, and legumes. In western countries, the calcium intake of vegans and some vegetarians may be as much as 30% lower than recommended intakes. In cultures where low calcium intakes are the norm, health problems and bone loss could be attributed to factors other than vegetarianism. Recommended dietary calcium intakes for preventing bone loss in older adults appear to be higher than the current US recommendations. High soy protein diets have been theoretically implicated in causing increased calcium losses in the urine, but it is established that increased urinary calcium excretion does not necessarily reflect an adverse effect on calcium balance. In most Western countries, proteins are derived primarily from animal products, meaning vegetarians have lower protein intakes compared to omnivores, which detracts from their bone status. In general, vegetarians usually consume adequate amounts of protein when caloric intake is also sufficient. Lacto-ovo vegetarians usually have no problem consuming recommended dietary allowances for protein, while most vegans can consume a wide variety of plant foods and sufficient calories. However, elderly vegans who consume less protein, due to smaller appetites or impaired nutrient utilization, could be at risk of lower bone status. Studies have shown that when protein intake is controlled, there is no difference in calcium retention between an animal protein and plant protein diet. 26-29

Vegetarianism has become an increasingly popular diet in the Western world, with 2-7% of North Americans considering themselves vegetarians. Nutrition is one modifiable factor that can affect the preservation of bone mass and the prevention of osteoporosis. A diet rich in fruits and vegetables creates an alkaline environment in the body, leading to a neutralization reaction with acidic foods, such as grains, meat, fish, and hard cheese. Calcium is required to achieve maximum bone mass in the body and to prevent bone loss. However, research on whether a vegetarian diet provides enough calcium for the prevention of bone loss is conflicting. Mean calcium intakes of the two groups were 830 mg (vegetarian) and 1049 mg (omnivorous), and the respective whole body BMD's were 1.204 g/cm² and 1.226 g/cm². There was a significant correlation between BMD and calcium intake when both groups were combined. Stepwise regression analysis suggested that calcium intake was a significant independent determinant of BMD at several skeletal sites. This suggests that individuals with low calcium intakes are at increased risk of osteoporosis, although this is also influenced by other factors, including genetic ones, which determine peak bone mass. Calcium intake is not the sole determinant of bone health, and the complexity of nutrients available in a vegetarian diet provide a range of other benefits. A study conducted in Britain showed that a higher fruit and vegetable intake was correlated with greater bone mineral density at the hip. High protein intakes, particularly high consumption of animal proteins, have been associated with increased urinary calcium losses and may have a negative impact on the skeleton. As long as vegetarians are ensured a minimum protein intake, it is best that the protein source comes from foods that do not have negative effects on calcium metabolism. 30-34

There was no evidence that increasing the ratio of animal protein consumption to plant protein consumption had a detrimental effect on calcium metabolism or that high fiber diets increased the risk of depleting the skeleton of calcium. Vitamin D intake for vegetarians was less than a third of the recommended dietary allowance, with a mean intake of only 3.4 micrograms. This is due to the fact that calcium is found in large amounts in dairy products and vegetarians tend to consume lower amounts of this food group. The main source of vitamin D for many people is through sunlight exposure and the synthesis of vitamin D in the skin. Mushrooms that have been exposed to ultraviolet light are the only vegetarian source of vitamin D, therefore, many vegetarians are at risk of vitamin D deficiency. Vitamin D levels in the skin are influenced by exposure to sunlight, which converts it into provitamin D₃ and vitamin D₃. Prolonged UV light exposure does not result in toxic levels of vitamin D₃ and its degradation product, lumisterol. Exposure to sunlight for 10 minutes at noon in summer in southern Europe and 20 minutes in northern Europe provides the equivalent of ingesting 200 IU vitamin D. In the US, advice to expose hands and face to sunlight for 5-10 minutes, 2-3 times per week is given, but irradiance data has shown that this length of exposure, arms and face exposure, would not result in raising body vitamin D levels above 8ng/mL throughout a whole year at most latitudes. Vitamin D₃ is 5 times more active than the D₂ form and has a number of biological actions other than those related to calcium homeostasis. There is a metabolic payment for vitamin D production and IQ differences with higher vitamin D levels, leading to speculation that vitamin D may have an effect on cognitive function. 35-28

The importance of protein for maintained bone health is well documented, with approximately 50% being found in bone. A recent study by the Nutritional Epidemiology Program at the Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University assessed the impact of protein on bone mineral density. The study concluded that "elderly people with higher intakes of animal protein, particularly women, sustained less age-related bone loss." The combination of nutrients is essential for achieving the greatest effect on bone health. While drug therapies like alendronate have been used to treat osteoporosis, dietary supplements combining calcium and other nutrients have rarely been tested for their impact on bone loss. Studies have shown that calcium has a greater impact on bone when the diet has sufficient other nutrients providing a favorable environment for calcium absorption and retention. Stephensen *et al.*, hypothesized that adequate vitamin K is important for postmenopausal women in slowing the rate of bone turnover that leads to menopausal bone loss. Heaney *et al.*, suggested a 'triage theory' that protein, potassium, and phosphorus are involved in an acute regulatory response to maintain mineral homeostasis, and when these nutrients are chronically insufficient, they take priority over calcium, leading to negative calcium balance and loss of bone mass. 36-39

An old study by Marsh AG, Sanchez TV, Mickelsen O, Keiser J, and Mario Savellano studied 25 postmenopausal women and found that vegetarians do not consume dietary sulfur-containing amino acids (methionine and cysteine), which are the prime source of calcium. High protein diets make the blood slightly acidic, causing a mild but long-term acidosis that promotes the resorption of alkaline salts from the bone. The best dietary means to preserve a high bone mass is to maintain an alkaline environment through the consumption of more fruit and vegetables, as this increases the potassium and bicarbonate content of the body. 40-41

A survey of over 20,000 British men and women from the European Prospective Investigation into Cancer and Nutrition (EPIC)-Oxford study found that vegetarians had lower calcium intakes than their omnivorous counterparts. This is consistent with previous studies, such as a German study comparing the dietary intakes of 198 vegetarians and 89 non-vegetarians. A recent study that recruited postmenopausal Asian women in the United States found that vegetarians had lower calcium intakes than non-vegetarians, with 59% of the vegetarians having calcium intakes below the estimated average requirement (EAR) compared to 55% of non-vegetarians. In India, vegetarians tend to have lower osteoporosis rates than their omnivorous counterparts due to limited consumption of dairy products and foods rich in calcium. The typical Western vegetarian diet is high in fruit and vegetables, with an increased intake of potassium, magnesium, and vitamin K from these foods. Some evidence has shown that these nutrients promote bone health, providing some protection from a low BMD. Soy is also a staple part of the vegetarian diet, and there is emerging evidence suggesting that isoflavones may be protective to bone. 42-43

The most straightforward way to increase calcium and retard bone loss in vegetarians is by using calcium supplements. Many studies have shown that a high calcium intake is positively associated with greater BMD. A randomized controlled trial by Lau *et al.*, compared the effect of three calcium supplement doses with a placebo in 200 postmenopausal women over two years, finding that BMD at the lumbar spine and trochanter increased significantly in the three supplement groups with the highest dose (800mg). Another trial by Meyer and Kessenich tested the effect of 1000mg calcium supplement in 48 younger women over one year, finding that BMD at the mid radius had increased in the supplement group while the placebo group had decreased. A meta-analysis by Recker *et al.*, found that calcium supplement doses of 500-1500mg/day produce a 1-2% increase in BMD, corresponding to a 10-20% decrease in fracture risk.

CONCLUSION

Our study found that the vegetarian diet had a statistically significant impact on the bone mineral density (BMD) of the Jordanian patients we studied. These patients may be at a higher risk of osteoporotic fractures. This effect was more pronounced when the vegetarian diet shifted towards a solely vegan diet, even after accounting for the size of the covariate related to supplemental calcium administration. Our conclusion emphasises the significance of adopting conservative strategies when transitioning to a vegetarian diet, rather than relying solely on calcium or vitamin D supplements.

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